junction. This wide space is encumbered with a mass of sand banks. The width of the Humber below the junction averages about 4500 feet, and this channel also feeds the Ouse, which is a continuation of the Humber. This width is double that of the Trent and Ouse combined. The rise of ordinary spring tides at Trent mouth is 15 feet, increasing at equinoctial tides to 19 feet. The tide has a run of 47 miles up the Trent, and reaches to 87 miles from the North Sea, the flood lasting three hours and the ebb nine hours.

The bore, or aeger, is caused by the check of the tidal flow through the shoal water of the sand banks and the contraction of the waterway, the tidal current overrunning the transmission of the foot of the wave. It first assumes a crest somewhere between Burton Stather, 3 miles from the mouth of the Trent, and Amcotts, 2 miles further on, depending on the condition of the tide, the water rising almost simultaneously 3 feet. In ordinary spring tides the bore does not extend more than 7 or 10 miles above Gainsborough. In high spring tides it diminishes to 1 foot in height at Torksey, 35 miles from the mouth of the river, and then gradually dies out.

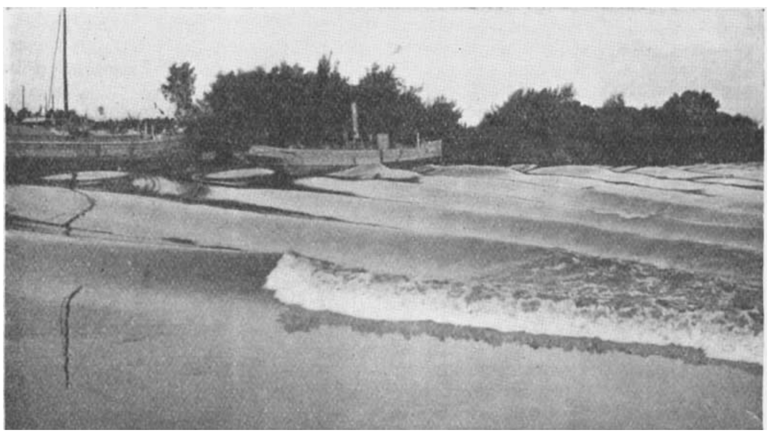

FIG. 1.—The Aeger in the Trent.

The bore was to be seen under exceptionally favourable conditions on September 30 and October 1 last, being the second and third days after the new moon. The tides were laid down in the Admiralty tide tables for the Humber as the largest of the year. The moon was in perigee on September 29, and had 11·21 degrees south declination. The wind was from N.E. to N.W., a direction which brings the largest tides, and was blowing at Spurn with a force of from 6 to 7. Inland the force was only about 3 on the Beaufort scale. There was a limited quantity of fresh water running down the river, the velocity at low water being 2 miles an hour. The depth in the channel between Gainsborough and the Humber is now about 6 feet, but there are several shoals with not more than 2 feet to $2\frac{1}{2}$ feet over them. The tide was exceptionally high, rising in the Humber at Hull nearly 3 feet higher than ordinary spring tides, and within 10 inches of the record tide of March, 1883.

The bore could be heard approaching about half a mile from the place of observation, and passed with a crest in the middle of the river of from 4 feet to $4\frac{1}{2}$ feet extending across the full width of the river, which is here about 200 feet at high water. At the sides the breaking wave rolled along the banks 6 feet or 7 feet high. The crest was followed by five or six other waves of less height, terminating in a mass of turbulent broken water for a distance of 100 yards. The velocity of the wave, as nearly as it could be measured, was about 15 miles an hour, the current running up after the bore had passed at the rate of $4\frac{1}{4}$ miles an hour, and at its maximum, about half flood, 5 miles an hour. The tide rose 4 feet in the first four minutes after the arrival of the bore, 5 feet in the first half hour, and 8 feet in two hours, when it attained its maximum height and commenced to fall; but the tide continued running up the river for another hour after this, at the reduced velocity of 2 miles an hour. There were some steamers and barges lying at the wharves, and a row-boat in the middle of the river. These rose with the wave and suffered no harm.

These bores were considered by the men on the river as fair specimens of those which come with high tides, and as never exceeded in height to any extent. When the river is full of fresh water and the ebb is heavy the bore is less pronounced, and does not show at all on neap tides. It was reported that at Owston Ferry, which is 8 miles nearer the Humber than Gainsborough, the crest of the aeger was 8 feet, but this was probably at the side of the river. A boat which was in the middle of the river when the wave came was for an instant completely out of sight of a spectator on the bank.

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In the Ouse during spring tides there is a less pronounced bore. In ordinary spring tides it commences at a shallow reach in the river at Sand Hall, 2 miles above Goole, attains its greatest height 4 miles above Selby, and then gradually dies out. The crest of the bore is from 2 feet to 3 feet, and the breaking wave at the sides 6 feet or 7 feet. In summer, when the ebb current is low, the aeger reaches Naburn with a crest 1 foot 6 inches high. Since the improvement of the channel of the river below Goole these aegers have become smaller.

W. H. WHEELER.

SURVEY OF THE SIMPLON TUNNEL.

WE have appreciated many of the difficulties the engineers encountered in the construction of the Simplon Tunnel and have offered our congratulations on the successful completion of the work. But the difficulties that have been most readily apprehended have been those arising from the outburst of water from the hot springs in the track, the high temperature, and the mechanical boring and removal of the rock. In the happy completion of a task of great magnitude, which at one time threatened to end in a catastrophe, people are apt to forget the onerous preliminary work necessary to set out the line of the tunnel, to arrange the gradient so as to provide not only for efficient drainage at either end, but to secure the continuity of the separate tunnels at the point of junction, and so render it possible to work simultaneously at both ends. We are therefore glad to see an article by Prof. C. Koppe in *Himmel und Erde* for August [1] bringing these matters forward, and making us familiar with the work which has

[1] "Die Vermessungs- und Absteckungs-Arbeiten für den Simplon Tunnel."

been so efficiently carried out by Prof. Rosenmund of Zurich.

Before the work of boring and perforation can be begun, there are three elements which have to be determined with an accuracy which must be greater in proportion to the difficulties of construction. These are the direction, the length, and the altitude above sea-level. Assuming that the places of entrance and exit of the tunnel have been marked by suitable pillars, the determination of these three elements begins; and that of the level is the least difficult, because the surveying engineer trusts to direct measurements. By the aid of accurate levelling instruments, it is possible to derive the difference in altitude of two stations 50 kilometres apart with no greater error than 3 cm. This is effected by the use of the levelling staff, which is read by means of an accurate level, the staff being placed vertically at two stations a convenient distance apart, and the sum of the differences of each pair of readings being taken. The surveyor apparently trusts entirely to the accuracy with which his theodolite can be levelled. Several determinations of the difference of level of the two ends of the tunnel were made, but between the two last there was a discrepancy of only 2 cm., a more than sufficient degree of accuracy. The actual difference of level between the two ends was 52·439 metres.

The second element, that of the length of the tunnel, is to be derived indirectly from triangulation, the length being reckoned from the same points that have served for the determination of difference of level, and, as a matter of fact, these points are at some distance from the actual openings. A base line being given, the construction and the solution of the triangles present little difficulty, for here great accuracy is not required, and the probable error that Prof. Rosenmund was content to leave in his work amounted to ±0·7 metre. The distances measured are as follows:—

	metres
The length between the columns marking the axis of tunnel...	20,091·33
Distance of northern column from tunnel opening	317·78
Distance of southern column from tunnel opening	44·84
Actual length of tunnel	19,728·71

The third element, that of direction, at all times presents some difficulty, and, in the case of mountains, where local attraction enters as a disturbing factor, the problem requires very delicate treatment. In a tunnel 20 kilometres long, an error in direction of one minute, which is usually the limit of accuracy sought in technical work, would produce an error of 6 metres, and the tenth part of such an error would be too great. Recourse is necessarily had to triangulation, and the angular measurements must be made with the greatest care. Well-defined signal posts must be erected to mark the angles of the selected triangles, and the points of reference in these pillars defined with the utmost accuracy. The form which Prof. Rosenmund preferred consisted of cylindrical towers of brick about eight feet high, of which the axis was an iron tube the upper edge of which reached the top surface of the tower. A wooden pole carried this iron tube vertically upwards, and the whole was surmounted by a conical tin covering, the highest point of which was vertically over the centre of the iron axis. Eleven of these piers were erected, and when signals were made from any pillar the conical top was removed, and the theodolite was placed centrally over the middle of the iron tube in the cylindrical tower, which afforded a solid support for the instrument and permitted accurate observation of the other stations. With the care exercised, it might have been anticipated that the sum of the angles of any triangle would differ from 180° by the known amount of the spherical excess, within the errors of observation. But the discrepancies were much larger, varying from 4 to 8·5 seconds, and these deviations could be explained only by attributing to the mountain an attractive force, which sensibly displaced the direction of the plumb-line. In other words, the theodolite was not placed horizontally. The amount of the deviations from the vertical, with the azimuths in which they occur, is shown in the following table:—

Station	Deviation from vertical ″	Azimuth
North point of axis... ...	13·9 ...	248 26
Oberried	19·1 ...	195 12
Birgischwald	16·4 ...	188 5
Rosswald	23·6 ...	262 56
Spitzhorn	17·5 ...	314 18
Monte Leone...	0·0 ...	0
Hüllehorn	8·2 ...	244 3
Seehorn	5·6 ...	75 28
Alpe Wolf	11·4 ...	36 46
Genuina	9·1 ...	192 3
South point of axis... ...	5·8 ...	139 11

Assuming these deviations from the vertical to arise from the attraction of the mountain mass, an hypothesis which was confirmed by rigorous astronomical observation, it was found possible to reduce the closing errors of the triangles very materially. The solution of the whole network of triangulation showed that the tunnel's axis was fixed with a probable error of ±0″·7, and that the direction of the tunnel could be fixed with sufficient accuracy by pointing the telescope, placed on one of the piers at the entrance of the tunnel, to any other signal tower, and revolving the telescope through a known angle.

It would be interesting to enter into the details by which the path of the tunnel was checked as the work progressed, more especially as curious refractive effects, akin to those seen in "mirage," occurred to render the observations somewhat difficult and uncertain. These disturbing effects were more noticeable when observing towards the north end of the tunnel, where the difference of temperature between the internal and external atmosphere was greatest. On the southern side, the external air being warmer than on the north side, the "mirage" was not so conspicuous. But we have only space to refer to the degree of success which resulted from the care bestowed on this difficult undertaking—a success which could not be adequately tested until the junction of the engineering parties in the middle of the tunnel was effected. To take the three elements in order, it was found that the level agreed within 0·1 metre of the calculations. The length as measured differed 2 metres from the calculated value, but, as mentioned, this was a factor in which great accuracy was not needed, because, if the direction were given correctly, it was only necessary to continue the borings until the engineers from the south and north sides met in the middle. The direction was most satisfactory. The wall of one tunnel was absolutely continuous with the wall of the other; an attempt was made to compare the opposite walls of the tunnel for confirmation, but this attempt was frustrated by a projecting piece of rock. No better result could have been anticipated, and the utmost credit attaches to Prof. Rosenmund and his assistants.

W. E. P.